Remarks/Arguments

These remarks are in response to the Office Action dated August 1, 2005. This reply is timely filed. At the time of the Office Action, claims 1-25 were pending in the application. 1-4, 6-12, 14-21, and 23-25 were rejected under 35 U.S.C. §103(a). Claims 5, 13 and 22 were objected to as being dependent upon a rejected base claim, but were indicated as allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. Claims 2, 5, 13, 18 and 22 have now been amended. Claim 2 was amended to correct a minor grammatical error. The rejections are set out in more detail below.

I. Allowable Subject Matter

Applicants note with appreciation that the Examiner has indicated that claims 5, 13, and 22 would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. In response, these claims have now been amended as appropriate in each case to place them in condition for allowance. Please charge Deposit Acct. No. 50-2884 in the amount of $600 for three (3) additional independent claims pursuant to Fee Code 1201.

II. Brief Review of Applicants' Invention

Prior to addressing the Examiner's rejections on the art, a brief review of Applicants' invention is appropriate. The invention relates to a transformer and methods of forming a transformer in a ceramic substrate. The method can include the steps of forming a plurality of conductive coils that comprise one or more turns about an unfired ceramic substrate. The method can also include the step of co-firing the unfired ceramic toroidal core region, the unfired ceramic substrate, and the conductive coil to form an integral ceramic substrate structure with the conductive coil at least partially embedded therein.

To further emphasize the novel features of Applicant's invention, it is helpful to discuss the related art. When forming toroidal transformers, it can be advantageous to form a core region of the toroidal transformer of a material having a relative permeability

value that is larger than one (Applicant's specification, ¶ 3). In order to provide such a high permeability core region, conventional approaches have formed cores in individual ceramic layers. In these convention methods, after the core is formed in an unfired ceramic layer, high permeability material, such as ferromagnetic metal material, is inserted within the core. While providing acceptable results, the foregoing technique in the prior art involves additional processing steps that are inconsistent with standard LTCC processing.

III. Claim Rejections Under 35 U.S.C. §103(a)

Claims 1, 2, 8, 10, 17-19, and 23 have been rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 6,820,321 to Harding ("Harding") in view of U.S. Published Application No. 2004/0124961 to Aoyagi ("Aoyagi") and in further view of Japanese Published Application No. 2001267129 assigned to Murata ("Murata"). Harding discloses methods of constructing inductive components, namely embedded toroidal transformers (Harding, Abstract). The Harding reference includes a toroidal transformer core and a substrate, both made from ferromagnetic metal material (Fig. 3A; col. 2, lines 18-22; col. 5, lines 21-29). The transfomer core is wound with copper wire to form a number of multiple turn windings (Fig. 3B; col. 2, lines 1-14).

Harding teaches numerous ways in which to embed the ferromagnetic metal core within the substrate. One method of fabrication can include embedding several ferromagnetic metal slabs between printed circuitry (col. 1, lines 64-66). Another method includes embedding several ferromagnetic metal pieces between the top and bottom layers of a printed circuit board (PCB) circuits (col. 4, lines 38-43). A panel is formed to accommodate each ferromagnetic metal core piece. Yet another method teaches that the core can be formed by a multi-layer series of thin concentric ferromagnetic metal rings supported on a flex circuit or PCB (col. 2, lines 18-22).

However, the Harding reference fails to teach that the core and substrate are of a ceramic material, as is recited by Applicants in amended independent claims 1, 10, and 18. Applicants' amended independent claim 1 recites a transformer embedded in an LTCC substrate comprising a ceramic substrate and a ceramic toroidal core embedded within the ceramic substrate. Applicants' amended independent claim 10 recites a

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method for forming a transformer in a ceramic substrate. Claim 10 further recites the step of forming at least one conductive coil of a plurality of turns about an unfired ceramic toroidal core region defined within an unfired ceramic substrate. Moreover, Applicants' amended independent claim 18 recites a method for forming a transformer in a ceramic substrate. Claim 18 further recites the step of forming a plurality of vias and traces in an unfired ceramic substrate to define at least one conductive coil of a plurality of turns about an unfired ceramic toroidal core region defined within an unfired ceramic substrate

Instead, Harding teaches in a first embodiment that both the core and substrate are made of a <u>ferromagnetic metal material</u>. (Harding, Abstract). In a second embodiment, Harding teaches that the core of the transformers comprises cores formed by a multi-layer series of thin concentric ferromagnetic metal rings supported on a suitable substrate such as a flex circuit or printed circuit board (col. 2, lines 18-22). Notably, Harding does not disclose a method for manufacturing a toroidal transformer in a ceramic substrate. According to Harding, "[c]opper circuit patterns 92 corresponding to the desired windings are formed on an [sic] epoxy sheets 110 which are glued to the top and bottom surfaces 112, 114 of the slab by adhesive 115. The cores 90 are thus contained in the circuits 92 by a lamination process." (Figs. 5-7; col. 4, lines 21-28). Via holes are formed through the composite FLEX layers and core.

The foregoing distinction is important. One skilled in the art would recognize that the epoxy sheet layers disclosed in Harding would not be suitable for creating a toroidal transformer in a ceramic material. In particular, the toroidal ferromagnetic core in Harding would not be compatible with the ceramic co-firing process as recited by Applicants' claim 10 and amended claim 18. Claims 10 and 18 both recite "co-firing said unfired ceramic toroidal core region, said unfired ceramic substrate, and said conductive coil to form an integral ceramic substrate structure with said conductive coil at least partially embedded therein." Harding does not show Applicants' ceramic toroidal core integrally formed with a ceramic substrate. Instead, Harding discloses various methods of backfilling the core with ferromagnetic metal material. (Harding, col. 4, lines 21-67). Mere backfilling of material in this way does not result in a core that is integrally formed with the substrate. For the core to be integrally formed with the

substrate, both components must undergo a co-firing process that is not taught by Harding.

In contrast, claim 10 and amended claim 18 in the present application recite a process that avoids the need for the additional processing steps associated with the prior art. Rather than forming cavities/cores and inserting magnetic material, the present method forms entire layers of the substrate from ceramic material having a high permeability. These layers can be selectively arranged to intersect a core region of the toroidal transformer. The foregoing process can provide improved manufacturing efficiency as compared to conventional processes that require backfilling.

Aside from method claims 10 and 18, Applicants' apparatus claim 1 also recites that the "ceramic toroidal core is integrally formed with said ceramic substrate in a co-firing process." Similarly, Harding does not teach a ceramic toroidal core being integrally formed with a ceramic substrate in a co-firing process. In view of the foregoing arguments, Harding fails to disclose several important features of the Applicant's invention as recited in independent method claims 10 and 18, as well as apparatus claim 1.

Furthermore, the foregoing deficiencies of Harding are not corrected by the remaining references cited by the Examiner. Aoyagi discloses a printed inductor having a spiral coil formed outside a cavity (see Abstract). The invention includes an insulating ceramic substrate with the cavity extending in a direction orthogonal to that of the thickness of the insulating ceramic substrate. The cavity is backfilled with ferromagnetic metal material, such as ferrite (page 2, ¶ 29). Also, printed wiring lines are disposed on both the top and bottom faces of the insulating ceramic substrate (Fig. 4). Finally, the connecting terminals of the wiring lines are connected on both the top and bottom faces through holes (page 2, ¶ 23 and 26).

While Aoyagi discloses a ceramic substrate, it still fails to teach a ceramic core that can be integrally formed with the substrate as a result of a co-firing process. This feature is recited in method claims 10 and 18, as well as apparatus claim 1. Applicants' claim 1 recites that the "ceramic toroidal core is integrally formed with said ceramic substrate in a co-firing process." Applicants' claims 10 and 12 both recite "co-firing said unfired ceramic toroidal core region, said unfired ceramic substrate, and said conductive

coil to form an integral ceramic substrate structure with said conductive coil at least partially embedded therein." Instead, the Aoyagi core is back-filled with a ferromagnetic metal material, namely ferrite (page 1, ¶ 13). The ferromagnetic metal material is inserted into the cavity <u>after</u> baking the insulating substrate. (Aoyagi, page 2, ¶ 29). Consequently, Aoyagi's additional back-filling step fails to teach Applicants' integral formation of the toroidal core. In Applicant's invention, the core is integrally formed with the substrate because the two components are co-fired to form an integral unit.

Aoyagi also teaches away Applicants' method for reducing the processing steps required for producing a toroidal transformer that has a core permeability that is greater than one. Instead, Aoyagi requires additional processing steps that include drilling out a hole for the toroidal core, and backfilling the hole after a toroidal ferromagnetic core has been inserted. Applicants' invention avoids these additional processing steps. Applicants' method is advantageous in that LTCC structures can be constructed without altering conventional LTCC processing techniques. This is a significant departure from Harding and Aoyagi, which require that high permeability materials be inserted or backfilled in apertures that are formed in the substrate during the manufacturing process.

Similarly, Murata fails to make up for the deficiencies of Harding and Aoyagi. Murata teaches a small-sized chip inductor and a method for its manufacture (Murata, Abstract). The inductor is formed by stacking ceramic layers containing electrode coil conductors to form a spiral configuration (Murata, Fig. 3). According to Murata's English language abstract, both the substrate and core are made from ceramic material. The spiral coil is said to penetrate the ceramic core.

While Examiner is correct in that Murata discloses a ceramic core and substrate, there is no evidence to suggest that the ceramic core is integrally formed with the ceramic substrate as would be the case when these components are co-fired. Furthermore, Murata does not teach or suggest the formation of a "toroidal core" as recited in Applicants' claims 1, 10, and 18. Instead, Murata limits its disclosure to the presence of a substantially cylindrical core (See Figs. 1, 2). It is not at all apparent how the process disclosed in Murata could be used to create a toroidal inductor. The advantages of a toroidal structure is that it can substantially contain the magnetic field

produced by the transformer within the core region, thus decreasing RF leakage and interference with other nearby components.

In summary, while Harding, Aoyagi, and Murata individually teach certain elements that are present in Applicants' invention, all three references fail to teach the fact that the ceramic toroidal core is integrally formed with a ceramic substrate. The advantage of Applicants' invention is that one can use conventional LTCC firing techniques without having to undergo additional processing steps as shown in the cited art. Therefore, Applicants request that the Examiner withdraw the rejection of claims 1, 10, and 18 under §103(a).

Dependent claims, 4, 6, 7, 12, 14-16, 21, 24, and 25 have been rejected under 35 U.S.C. §103(a). However, in view of the arguments presented earlier regarding independent claims 1, 10, and 18, Applicants believe that these dependent claims are in condition for allowance at least on the basis of their dependence upon an allowable base claim.

Claims 3, 9, 11, and 20 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Harding, Aoyagi, Murata in view of U.S. Patent No. 6,791,496 to Killen et al. ("Killen et al."). Significantly, the invention disclosed in Killen et al. qualifies as prior art only under 35 U.S.C. §102(e). 35 U.S.C. §102(e) (2) states in pertinent part that a person shall be entitled to a patent unless the invention is described in a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent. However, the Examiner's attention is directed to 35 U.S.C. §103(c) (1). That statutory section provides that:

> Subject matter developed by another person, which qualifies as prior art only under one or more of subsections (e), (f), and (g) of section 102 of this title, shall not preclude patentability under this section where the subject matter and the claimed invention were, at the time the claimed invention was made, owned by the same person or subject to an obligation of assignment to the same person.
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> 35 U.S.C. §103(c) (1)

Applicant wishes to inform the Examiner that the present application and U.S. Patent No. 6,791,496 are commonly assigned to Harris Corporation of Melbourne,

Florida. Copies of the recorded assignment documentation are enclosed herewith for the Examiner's convenience. In view of the foregoing, Applicant respectfully submits that the combination of the invention described in Harding, Aoyagi, Murata, and Killen et al. cannot be properly used as the basis for forming an obviousness rejection under 35 U.S.C. §103. Accordingly, Applicant respectfully submits that dependent claims 3, 9, 11, and 20 are not obvious in view of the remaining cited references.

IV. Conclusion

Applicants have made every effort to present claims which distinguish over the prior art, and it is believed that all claims are in condition for allowance. Nevertheless, Applicants invite the Examiner to call the undersigned if it is believed that a telephonic interview would expedite the prosecution of the application to an allowance. In view of the foregoing remarks, Applicants respectfully request reconsideration and prompt allowance of the pending claims.

Respectfully submitted,

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